(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 951 968 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.10.1999 Bulletin 1999/43

(51) Int Cl.[6]: **B25J 9/16**

(21) Application number: **99303077.4**

(22) Date of filing: **21.04.1999**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **21.04.1998 JP 12536898**

(71) Applicant: **FANUC LTD**
Minamitsuru-gun, Yamanashi 401-0597 (JP)

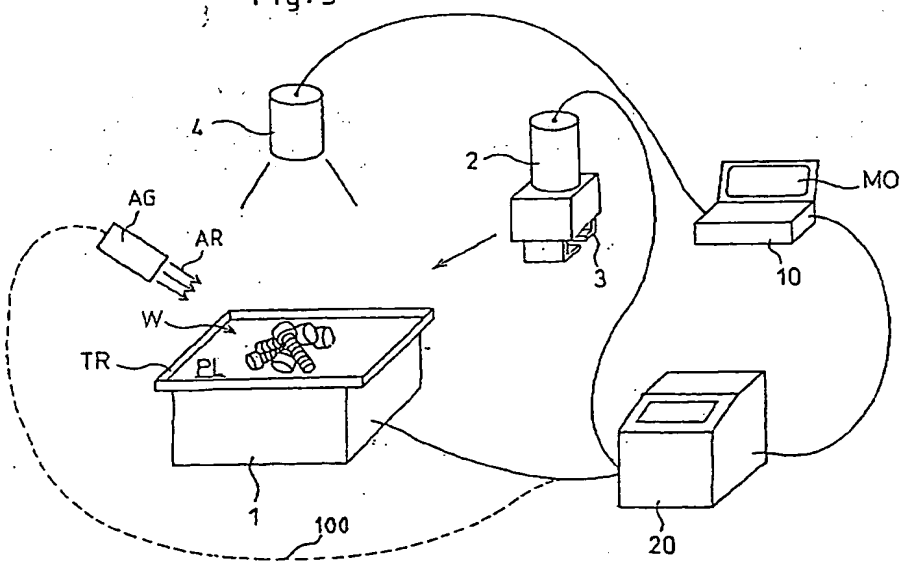
(72) Inventors:
- **Watanabe, Atsushi**
  Minamitsuru-gun, Yamanashi 401-0511 (JP)
- **Hara, Ryuichi**
  Fujiyoshida-shi, Yamanashi 403-0005 (JP)
- **Ban, Kazunori, Fanuc Manshonharimomi**
  Minamitsuru-gun, Yamanashi 401-0511 (JP)
- **Kumiya, Hidetoshi, Fanuc Dai3virakaramatsu**
  Minamitsuru-gun, Yamanashi 401-0511 (JP)

(74) Representative: **Billington, Lawrence Emlyn**
Haseltine Lake & Co.,
Imperial House,
15-19 Kingsway
London WC2B 6UD (GB)

(54) Article picking-up apparatus

(57) A group of bolts are supplied onto a placing surface of a tray, an isolated bolt is searched for by a visual sensor, and its deviation from a standard position at the time of teaching is determined. The isolated bolt is picked up by a robot to which a picking-up operation is taught which making a correction of the shift. If no isolated bolt is found, a shaking device 1 is operated to loosen the piled-up bolts, and an isolated bolt newly produced is again searched for by the visual sensor. The isolated bolt, if found, is picked up. The picking-up operation may be performed by searching for an isolated small set of bolts by using a three-dimensional visual sensor. Also, the piled-up bolts may be loosened or disentangled by using a robot equipped with a tool for levelling the pile of bolts or by using a gas jet.

Fig.3



EP 0 951 968 A2

BNSDOCID: <EP___0951968A2_I_>

Description

[0001] The present invention relates to an automation technology for handling articles such as assembly workpieces in a factory or other places. More particularly, it relates to an apparatus capable of picking up articles one by one by using an industrial robot (hereinafter referred to as a robot) when many articles are placed in a disorderly piled-up manner on a table or on an article placing surface of a box or the like.

[0002] In an assembly process in a factory, for example, work for picking up various articles is a basic work element which is indispensable for almost all cases. To automate this work, a robot or a system incorporating a robot and a visual sensor is used.

[0003] A problem with the conventional technology is that it is very difficult for the robot to hold and pick up an article one by one from many articles piled up disorderly.

[0004] For example, in the case where many (for example, five) workpieces W1 to W5 (for example, bolts) are piled up disorderly on a tray TR as shown in Fig. 1, it is not easy to pick up individual workpieces by a robot even with the aid of a visual sensor.

[0005] Especially when the holding posture of a robot hand requires a certain accuracy, for example, when the axial direction of bolt must be made agree with the Z-axis direction of the tool coordinate system, this picking-up work is especially difficult to do.

[0006] To solve this problem, conventionally in many cases, the workpieces W1 to W5 are lined up or positioned so as to preclude the lapping before the picking-up work is performed by the robot as shown in Fig. 2. If the visual sensor is used, the decreased accuracy of lining-up or positioning of the workpieces W1 to W5 is allowed, and in some cases, some lapping of the workpieces is also allowed.

[0007] However, to realize the state as shown in Fig. 2 or a state similar to this state, manual work or a large-scale automatic lining-up/positioning mechanism is needed, which causes an obstacle to automating the process by using a simple system. Also, with either manual work or the use of automatic mechanism, the process time is liable to be prolonged by the lining-up or positioning.

[0008] An object of the present invention is to provide an apparatus capable of picking up articles exactly one by one from many piled-up articles without a manual operation for lining-up or positioning the articles and without using any special lining-up/positioning mechanism.

[0009] In the present invention, to attain the above object, even in the case where many articles are piled up, the piled-up articles are loosened (including the decreasing of the degree of pileup of articles at least partially and the elimination of the pileup) by directly or indirectly giving a proper physical action to a group of articles, and the loosened article can be picked up one by one by a robot.

[0010] The article picking-up apparatus in accordance with the present invention comprises a robot; articles placing means; loosening means having a function of giving a physical action to a group of articles mounted on said articles placing means in a piled-up state to loosen the piled-up state: and a visual sensor which searches for a group of articles on the articles placing means to find at least one holdable article that can be held by the robot in accordance with a predetermined criterion, and obtains data concerning the position of the holdable article. The robot is operated so as to hold and pick up the holdable article by using the data concerning the position of the holdable article.

[0011] As the visual sensor, either a two-dimensional visual sensor or a three-dimensional visual sensor may be used.

[0012] As an example of criterion, an isolated article which is not lapped over any another article is taken as a holdable article. Also, as another example of criterion, one isolated article or an isolated small set consisting of a certain number ("N" number) or less articles contacting with each other is taken to be a set of holdable articles. The latter criterion is suitable to the picking-up apparatus using a three-dimensional visual sensor.

[0013] Here, the aforementioned value of N (for example, five) is selected as a value such that the robot can pick up individual articles from the maximum N number of articles with the aid of the visual sensor even if they are in contact with each other or piled up.

[0014] A group of articles to be picked up is subjected to a physical action. This physical action is typically an oscillating motion. As means for giving the oscillating motion to the articles to loosen or disentangle the articles, a shaking device attached to the articles placing means or a robot to which an operation for oscillating the articles placing means is taught can be used Also, as loosening means of another type for giving a physical action to a group of articles, a tool for loosening the piled-up articles is mounted to the robot. The robot is taught and operated so as to level the pile of a group of articles by using the tool to establish a state in which the articles are isolated or a state in which N number or less articles are in contact with each other.

[0015] According to the present invention, the lining-up or positioning of articles, which have conventionally been needed before the holding and picking-up operation of robot is started, becomes unnecessary. Therefore, manpower or a special-purpose mechanism for lining up or positioning the articles can be saved. As a result, great advantages can be obtained in terms of work efficiency and economical cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The foregoing and other objects and features of the invention will become apparent from the following description of preferred embodiments of the invention with reference to the accompanying drawings, in which:

BNSDOCID: <EP___0951968A2_I_>

Fig. 1 is a perspective view showing a typical state in which bolts to be picked up are piled up;
Fig. 2 is a perspective view showing a typical state in which the bolts shown in Fig. 1 are lined up or positioned;
Fig. 3 is a schematic view showing a general arrangement of a system used in a first embodiment of the present invention;
Fig. 4 is a block diagram showing a somewhat detailed configuration of the system shown in Fig. 3;
Fig. 5 is a flowchart showing the outline of picking-up process in the first embodiment
Fig. 6 is a plan view for illustrating the search for an isolated bolt;
Fig. 7 is a schematic view showing a general arrangement of a system used in a second embodiment of the present invention;
fig. 8 is a block diagram showing a somewhat detailed configuration of the system shown in Fig. 7
Fig. 9 is a flowchart showing the outline of picking-up process in the second embodiments
Fig. 10 is a perspective view showing a state in which the top surface of a tray is scanned two-dimensionally by a spotlight of a projector
Fig. 11 is a view for illustrating the occupied area of bolts;
Fig. 12 is a view for illustrating the height of the top of a group of bolts;
Fig. 13 is a perspective view for illustrating a state in which the portion around a ridge extending from the top is scanned by a spotlight and a positional shift of an uppermost bolt;
Fig. 14 is a view for illustrating an oscillating motion given by a robot; and
Fig. 15 is a view for illustrating for an operation for loosening the piled-up articles by using a loosening device supported by the robot.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[First embodiment]

[0017] Fig. 3 is a schematic view showing a general arrangement of a system, which includes an article picking-up apparatus in accordance with the present invention, used in a first embodiment of the present invention. In this embodiment, the articles to be picked up are a large number of bolts. In Fig. 3, five bolts are shown as an example, and the whole thereof is indicated by a bolt group W.

[0018] The bolt group W is supplied by using a supply device (not shown) in such a manner as to be disorderly piled up on a placing surface PL of a tray TR. The tray TR is attached to a shaking device 1 so that a physical action is given to the bolt group W. When the shaking device 1 is operated, the tray TR is oscillated, so that the piled-up bolt group W is loosened or disentangled.

[0019] A CCD camera 4, which has a field of view covering almost the whole of the tray TR, is provided at an appropriate place just above the tray TR, and a robot 2 (only the hand portion thereof is shown) is provided at an appropriate place near the tray TR. The robot 2 is equipped with a hand 3 suitable for holding the individual bolt.

[0020] An image processing device 10 is connected to the camera 4. Both of the image processing device 10 and the camera 4 constitute a publicly known two-dimensional visual sensor. Reference character MO denotes a monitor display consisting of a liquid crystal display, a CRT, or the like attached to the image processing device 10, which can display images obtained by the camera 4 or images processed by the image processing device 10.

[0021] Reference numeral 20 denotes a robot controller that is also used as a controller for the whole system. The robot controller 20 is connected to not only the robot 2 but also to the shaking device 1, the image processing device 10, and necessary external devices (for example, a mechanism for supplying the bolt group W to the tray TR). The following is a rough description of the roles of the principal elements.

Shaking device 1:

[0022] The shaking device 1 oscillates the tray TR on command from the robot controller 20 to give an oscillating motion to the bolt group W. For the *shaking* device itself, for example, a type using an electromagnet and other types are publicly known. Therefore, the details are omitted.

Two-dimensional visual sensor:

[0023]

(1) The two-dimensional visual sensor photographs the bolt group W by using the camera 4 on command from the robot controller 20 when the shaking device 1 is stopped, and takes the image in the image processing device 10.
(2) The image prodessing device 10 analyzes the taken-in image, and performs "the search for holdable bolt" and "the detection of position of the found holdable bolt." The result is sent to the robot controller 20. Here, a "holdable bolt (a holdable article in general; the same also applies to the following)" means a bolt tha can be held exactly by the robot 2. The presence of holdable bolts is judged in accordance with a preset criterion. In this embodiment, an "isolated bolt" is taken as the holdable bolt, as described later.

BNSDOCID: <EP___0951968A2_I_>

Robot controller 20:

[0024]

(1) The robot controller 20 operates the shaking device 1 at a predetermined time for a fixed period of time (for example, for several seconds) to give an oscillating motion to the bolt group W, by which holdable bolts (in this embodiment, isolated bolts) are produced.
(2) The robot controller 20 operates the visual sensor (camera 4 and image processing device 10) at a predetermined time to perform photographing, image accumulation, image processing, etc. Also, it receives the data representing the success in search of holdable bolts and the data concerning the positions of the holdable bolts from the image processing device 10.
(3) When a holdable bolt exists on the tray TR, the robot controller 20 starts an operation program (a picking-up operation has been taught in advance) and operates the robot 2 to pick up an individual holdable bolt. In the operation program, approach for picking-up operation, holding, and transfer after holding have been taught. The teaching may be performed by placing a single bolt lying in standard posture at a standard position on the tray TR and by making the robot controller 20 store the picking-up operation by using a teaching playback system.

[0025] At the time of playback operation for the actual work, the approach path and holding posture of the robot are corrected on the basis of the data concerning the position (including posture; the same also applies to the following) of a holdable bolt (in this embodiment, an isolated bolt; the details are described later) output from the visual sensor.

[0026] Fig. 4 is a block diagram showing a somewhat detailed configuration of the above-described system. Referring to Fig. 4, the image processing device 10 has a central processing unit (hereinafter referred to as a CPU) 11. The CPU 11 connects with a frame memory (image memory) 12, a control software memory 13 configurated by a ROM, a program memory 14 configured by a RAM etc., a data memory 15 configured by nonvolatile RAM, a camera interface 16, an image processing processor 17, a communication interface 18, and a monitor interface 19 via a bus BS1.

[0027] The communication interface 18 is connected to a communication interface 27 at the side of the robot controller 20, and signals representing data and commands are transferred via both of these interfaces. Also, the camera 4 is connected to the camera interface 16. Further, the monitor MO is connected to the monitor interface 19, so that the image captured by the camera 4, the image invoked from the frame memory 12, and the processed image (for example, a contour extract image) can be seen at an appropriate time.

[0028] The image captured by the field of view of the camera 4 is converted into a variable density image by grey scale and stored in the frame memory 12. The image processing processor 17 has a function of processing the image stored in the frame memory 12 on command of the CPU 11. The control software memory 13 stores the following programs and related parameters:

(1) A control program for the CPU 11 to control the visual sensor.
(2) A calibration program for setting a sensor coordinate system by using a jig.
(3) An image analyzing program for executing "the search for isolated bolt" and "the detection of position of the isolated bolt, " described later, by using the image processing processor 17.
(4) A program for sending and receiving data to and from the robot at appropriate timing.

[0029] The image captured by the camera 4, the image invoked from the frame memory 12, and the processed image (for example, a contour extract image) can be seen on a display screen of the monitor MO at an appropriate time.

[0030] On the other hand, the robot controller 20 has a central processing unit (CPU) 21. The CPU 21 connects with a ROM 22 for storing various control programs including a program for executing the processing for a picking-up operation, described later, a RAM 23 used for the temporary storage of calculation data etc., a nonvolatile memory 24 for storing teaching data and various parameters, a digital servo circuit 25 for controlling the individual axes of the robot body 2, a teaching panel 26 for performing manual operation, setting of coordinate system, position teaching, automatic operation (playback operation), etc. of the robot, and a general purpose signal interface 27 connected to the communication interface 18 at the side of the image processing device 10 via a bus BS2.

[0031] Next, the outline of process for executing the picking-up operation by using the above-described system will be described with reference to a flowchart shown in Fig. 5. The point of each step shown in Fig. 5 is as described below. In this process, it is assumed that the calibration of the visual sensor, and the teaching of approach, holding, transfer after holding, etc. for the picking-up operation have been finished.

[0032] Step S1: The bolt group W is photographed by the camera 4 on command from the robot controller 20, and the image is taken in the image processing device 10.

[0033] Step S2: The taken-in image is analyzed, and an isolated bolt is searched for as a holdable bolt . Here, the "isolated bolt" means a bolt such that the contour of one bolt is isolated (not lapped) from other bolt images on the screen as indicated by reference character A or B in Fig. 6. As an image "processing software for searching for an isolated bolt, the publicly known pattern

BNSDOCID: <EP___0951968A2_I_>

matching method is available.

[0034] According to this method, a standard pattern (here, a bolt contour image) representing the shape and size of an article to be searched for is stored in the image processing device 10 in advance, and the contour image element captured actually is compared with the standard pattern. In this example, the contour image elements A, B and C are compared with the standard pattern in succession. The contour image elements A and B are apparently capable of being lapped on the standard pattern (in other words, they can be matched with each other), so that they are judged to be the images of isolated bolts. The contour image element C is apparently incapable of being lapped on the standard pattern (in other words, they cannot be matched with each other), so that it is judged not to be the image of isolated bolt.

[0035] Step S3: If at least one isolated bolt is found by the search of isolated bolt, the process proceeds to Step 54. If none is found, the process proceeds to Step S5. For example, in the case shown in Fig. 6, the process proceeds to Step S4.

[0036] Step S4: The position of the found isolated bolt is detected, and a deviation from a standard position in teaching (indicated by vector T) is determined. For example, in the case shown in Fig. 6, taking the image of a first found isolated bolt as A, a matrix ΔA (homogeneous transformation matrix of four lines and four rows) representing the relationship between vector A and vector T is determined. The matrix ΔA is calculated assuming that vector A and vector T lie on a fixed plane (XY plane: $Z = 0$) and the Z component of vector T is zero. The rotation component of matrix ΔA represents the rotation on the XY plane, and the translation component thereof represents the translation on the XY plane.

[0037] Step S5: The operation program having been taught in advance is started, and the robot 2 is operated to pick up isolated bolt A. At this time, the approach path and holding posture of robot are corrected in accordance with the data of matrix ΔA. After the operation is finished, the process returns to Step S1. Subsequently, steps S2 and S3 are executed again. If an isolated bolt remains, the process further proceeds from Step S3 to Step S4. In the case shown in Fig. 6, a matrix ΔB representing the relationship between vector B and vector T is determined this time.

[0038] Step S6: In the case where no isolated bolt is found, two situations are assumed. That is to say, if a bolt image is present, but no isolated bolt is found (two or more bolts remain), the process proceeds to Step 57. If a bolt image itself is absent, the process is finished because this state means that all bolts have been picked up.

[0039] Step S7: The shaking device 1 is operated for a fixed period of time to give an oscillating motion to the bolt group remaining on the tray TR at this point of time. After the operation of the shaking device 1 is stopped, the process returns to Step S1. In many cases, by the oscillating motion, some or all of the piled-up bolts are separated, and one or more isolated bolts are produced newly.

[0040] If an isolated bolt is produced newly, the processing cycle of Step S1 → Step S2 → Step S3 → Step S4 → Step S5 → Step S1 is executed. If the oscillating motion is insufficient and therefore no isolated bolt is produced newly, the process proceeds from Step S1 to Step S2 to Step S3 to Step S6 to Step S7, and the shaking device 1 is operated for a fixed period of time again, by which an oscillating motion is given. After the operation of the shaking device 1 is stopped, the process returns to Step S1. Subsequently, this cycle is repeated until the judgment result in Step S3 becomes Yes.

[0041] By carrying out the aforementioned process, isolated bolts are picked up one after another. When all bolts have been picked up, the judgment result in Step S6 is No, and the process is finished.

[Second embodiment]

[0042] In a second embodiment, a three-dimensional visual sensor is used in place of the two-dimensional visual sensor. Also, here is described an example in which a spotlight scanning type projector incorporating a spotlight projector capable of random scanning and a PSD position sensitive light detector) 50 is used as the three-dimensional visual sensor. The three-dimensional visual sensor of any one type, for example, a slit light projector type three-dimensional visual sensor incorporating a slit light projector and a CCD camera may be used. Further, as a criterion for searching for a holdable bolt, a criterion different from that of the first embodiment (the details are described later) is used.

[0043] Fig. 7 is a schematic view showing a general arrangement of another system to which an article picking-up apparatus and method in accordance with the present invention are applied as the second embodiment of the present invention. In this embodiment as well, the articles to be picked up are a large number of bolts. In Fig. 7, five bolts are shown as an example, and the whole thereof is indicated by a bolt group W.

[0044] As in the case of the first embodiment, the bolt group W is supplied by using a supply device (not shown) in such a manner as to be disorderly piled up on a placing surface PL of a tray TR. The tray TR is attached to a shaking device 1 so that an oscillating motion is given to the bolt group W. A robot 2 (only the hand portion thereof is shown) is provided at an appropriate place near the tray TR, and a projector 40 which covers almost the whole of the tray TR as a scannable region and a PSD 50 equipped with a lens system LS are disposed at appropriate places around the tray TR. The projector 40 is made up of a laser beam source 41, deflectors 42 and 43 in which two rotating deflection axes intersect at right angles, and mirrors MX and MY attached to the deflectors 42 and 43, respectively.

[0045] The driving control of the projector 40 and the

BNSDOCID: <EP__0951968A2_I_>

processing of output signals of the PSD 50 are carried out by a projector driving/signal processing device 60. The projector 40, PSD 50, and projector driving/signal processing device 60, together with a part (software and hardware for searching for a holdable bolt in accordance with the criterion) of robot controller 30, constitute the publicly known three-dimensional visual sensor.

[0046] As in case of the first embodiment, the robot 2 is equipped with a hand 3 suitable for holding the individual bolt. Reference numeral 30 denotes a robot controller which is also used as a controller for the whole system. The robot controller 30 is connected not only to the robot 2 but also to a shaking device 1, the projector driving/signal processing device 60, and necessary external devices (for example, a mechanism for supplying the bolt group W to the tray TR). The following is a rough description of the roles of the principal elements

Shaking device 1:

[0047] The shaking device 1 is the same as that of the first embodiment. It oscillates the tray TR on command from the robot controller 30 to give an oscillating motion to the bolt group W.

Three-dimensional visual sensor:

[0048]

(1) The projector driving/signal processing device 60, receiving a command from the robot controller 30 when the shaking device 1 is stopped, scans the bolt group W with a spot beam L1 projected from the projector 40, and carries out detection with the PSD 50 via the lens system LS. The data detected by the PSD 50 is processed by the projector driving/signal processing device 60, and the data concerning three-dimensional position for the bolt group W is collected. The collected data is sent to the robot controller 30.

(2) The spotlight projection type three-dimensional visual sensor itself is publicly known (for example, see Japanese Patent Application Laid-Open No. 6-229732 and Japanese Patent Application Laid-Open No. 7-270137). Therefore, the detailed description thereof is omitted, and only the measurement principle is briefly described. The deflectors 42, 43 control the directions of the mirrors MX and MY according to a set of voltage commands (Vx, Vy) issued from the projector driving/signal processing device 60.

[0049] Therefore, if the relationship between the voltage commands (Vx, Vy) and the position (equation of straight line) of the spot beam L1 is determined in advance by calibration, the spot beam L1 can perform scanning in a desired pattern by programming the timerelated change pattern of the voltage commands (Vx, Vy).

[0050] The spot beam L1 incident on a certain incident position P at any point of time produces a luminescent spot. This luminescent spot is detected by point Q on the light intercepting face of the PSD 50 via the lens system LS. The PSD 50 may be of a one-dimensional type. As the direct output of the PSD 50, two currents i1 and i2 according to the one-dimensional position of point Q are output. They pass through a publicly known analog signal processing circuit, and are converted into an output signal Vq representing the one-dimensional position of point Q.

[0051] The three-dimensional position of the incident position P is determined by solving, as simultaneous equations, the equation of straight line representing the spot beam L1 specified by (Vx, Vy) and the conditional expression that gives the output signal Vq for point Q. Actually, the relational expression P(x, y, z) = f(Vx, Vy, Vq) approximately representing the general solution of the above simultaneous equations is stored in advance in the projector driving/signal processing device 60 or the robot controller 30, by which the three-dimensional position of point P can be detected at any time.

Robot controller 30:

[0052]

(1) The robot controller 30 operates the shaking device 1 at a predetermined time for a fixed period of time (for example, for several seconds) to give an oscillating motion to the bolt group W, by which holdable bolts are produced. The definition (criterion) of the holdable bolt differs from that in the first embodiment, as described later.

(2) The robot controller 30 operates the spotlight scanning type three-dimensional visual sensor at a predetermined time to obtain the data concerning the three-dimensional position for the bolt group W.

(3) As in case of the first embodiment, when a holdable bolt is present on the tray TR, the robot controller 30 starts an operation program (for which a picking-up operation has been taught in advance) and operates the robot 2 to pick up an individual holdable bolt.

[0053] In the operation program, approach for picking-up operation, holding, and transfer after holding have been taught. The teaching may be performed by placing a single bolt lying in a standard posture at a standard position on the tray TR and by making the robot controller 20 store the picking-up operation by using a teaching playback system.

[0054] At the time of playback operation for the actual work, the approach path and holding posture of the robot are corrected on the basis of the data concerning the position of a holdable bolt (the details are described later) output from the three-dimensional visual sensor.

EPODOC: <EP__0951968A2_I_>

[0055] Fig. 8 is block diagram showing a somewhat detailed configuration of the system in the second embodiment. Referring to Fig. 8, the robot controller 30 has a CPU 31. The CPU 31 connects with a ROM 32 for storing various control programs, a RAM 33 used for the temporary storage of calculation data etc., a nonvolatile memory 34 for storing taught data and various parameters, a digital servo circuit 35 for controlling the individual axes of the robot body 2, a teaching panel 36 for performing manual operation, setting of coordinate system, position teaching, automatic operation (playback operation), etc. of the robot, and an input-output device (I/O) 37 via a bus BS. In particular, in this embodiment, the control program includes programs for executing the search for a holdable bolt, the detection of position of the holdable bolt, and the picking-up operation of the holdable bolt by means of the robot 2 (the details of processing will be described later).

[0056] The input-output device (I/O) 37 is connected to a projector driving section 61 and a PSD detection signal processing section 62 of the projector driving/signal processing device 60. The projector driving section 61 and the PSD detection signal processing section 62 each have a required CPU, memories, input-output device, and the like. The former is connected to the projector 40 to control the driving of the laser beam source 41 and the deflectors (galvanometers) 42 and 43, and the latter processes the output signals of the PSD 50, and sends signal Vq representing the position of detection point Q to the robot controller 30. The processing such as the acquisition of three-dimensional position data based on the voltage commands Vx, Vy, Vq and the subsequent search for a holdable bolt is performed in the robot controller 30.

[0057] Next, the outline of process for executing the picking-up operation by using the above-described system will be described with reference to a flowchart shown in Fig. 9. The point of each step shown in Fig. 9 is as described below. In this process, it is assumed that the calibration of the visual sensor, and the teaching of approach, holding, transfer after holding, etc. for the picking-up operation have been finished. Also, as a world coordinate system representing the three-dimensional position, a coordinate system in which a placing surface PL of the tray TR is taken as the XY plane (Z=0), and the vertical upward direction is taken as +Z axis direction is set in the system (robot controller 30).

[0058] Step K1: As shown in Fig. 10, the top surface of the tray TR is scanned two-dimensionally by the projector 40, and the three-dimensional position data concerning the incident point P of spotlight is collected. If Z>0, it is found that the incident point P of spotlight lies on a bolt. If Z=0, it is found that the incident point P of spotlight lies on the placing surface PL (where any bolt is absent) of the tray TR.

[0059] Step K2: As a first step for searching for an isolated small set including holdable bolts, as shown in Fig. 11, a bolt group such that the occupied area (area surrounded by reference characters a,b,c,... s,t,u) is not larger than the reference value 3S is searched for. Here, S is a reference value approximately representing an area occupied by a single bolt, and it is preferable that the optimum value be finely adjusted by tuning, the rule of thumb, etc. Generally, if Sis set to be smallish, a set consisting of four or more bolts can easily be excluded (that is, it is not judged to be an isolated small set).

[0060] Step K3: If at least one bolt group having an occupied area not larger than 3S is found in Step K2, the process proceeds to Step K4. If none is found, the process proceeds to Step K9.

[0061] Step K4: Atop (a point that gives the maximum Z-axis value) of the bolt groups is searched for based on the three-dimensional position data concerning the found bolt group.

[0062] Step K5: As shown in Fig. 12, if the top height is not larger than the reference value 3d, it is judged to be an isolated small set including holdable bolts, and the process proceeds to Step K6. If the top height exceeds the reference value 3d, it is judged that the bolt group consists of bolts piled up over and over again and is not a small bolt group including holdable bolts, and the process proceeds to Step K10.

[0063] Here, as additionally shown in Fig. 12, "d" is a reference value approximately representing a diameter (a height when the bolt is placed horizontally) of a single bolt, and it is preferable that the optimum value be finely adjusted by tuning, the rule of thumb, etc. Generally, if d is set to be smallish, a set consisting of four or more bolts can easily be excluded.

[0064] As explained above, the criterion in this embodiment is used for searching for an "isolated small set" from both of the viewpoints of occupied area and top height.

[0065] Step K6: As shown in Fig. 13, a ridge extending from the top is scanned by a spotlight, and the position data concerning the ridge is collected. Then, vector H representing the position of an uppermost bolt H is determined Generally, the Z component of vector H is not zero.

[0066] Step K7: A matrix ΔH (homogeneous transformation matrix of four lines and four rows) representing a deviation of vector H5 from a standard position (indicated by vector T) at the time of teaching is determined. It is to be noted that vector T lies on the XY plane, but vector H does not lie on the XY plane. The rotation component of matrix ΔH represents the rotation in the three-dimensional space, and the translation component thereof represents the translation in the three-dimensional space.

[0067] Step K8: The operation program having been taught in advance is started, and the robot 2 is operated to pick up uppermost bolt H. At this time, the approach path and holding posture of robot are corrected in accordance with the data of matrix ΔH. After the operation is finished, the process returns to Step K1.

[0068] Subsequently, steps S2 and the subsequent

BNSDOCID: <EP___0951968A2_I_>

steps are executed again. If an isolated small set remains, Step K8 is reached again, and the next bolt (for example, bolt I in Fig. 13) is picked up.

[0069] Step K9: As a case where the judgment result in Step K3 is No, two situations are assumed. That is to say, if the bolt image is present but no isolated small set is found (several or more bolts remain), the process proceeds to Step K10. If the bolt image itself is absent, the process is finished because this state means that all bolts have been picked up.

[0070] Step 10: The shaking device 1 is operated for a fixed period of time to give an oscillating motion to the bolt group remaining on the tray TR at this point of time. After the operation of the shaking device 1 is stopped, the process returns to Step K1. In many cases, by the oscillating motion, some or all of the piled-up bolts are separated, and one or more isolated bolts are produced newly.

[0071] If an isolated small set is produced newly, the processing cycle of Step K1 → Step K2 → ... → Step K8 → Step K1 is executed. If the oscillating motion is insufficient and therefore no isolated small set is produced newly, the shaking device 1 is operated for a fixed period of time again through Step K2 → Step K3 → Step K9 or Step K2 → ... → Step K5, by which an oscillating motion is given. After the operation of the shaking device 1 is stopped, the process returns to Step K1. Subsequently, this cycle is repeated until the judgment results in Step K3 and Step K5 become Yes.

[0072] By carrying out the aforementioned process, bolts are picked up one after another. When all bolts have been picked up, the judgment result in Step K9 is No, and the process is finished.

[0073] In the above two embodiments, the physical action applied to a group of articles to loosen the piled-up articles is an oscillating motion, and this oscillation motion is produced by the shaking device attached to the tray TR. However, the present invention is not limited to these examples.

[0074] For example, the physical action may be applied by a robot RB (which may be the same as or separated from a robot for holding the article). In this case, as shown in Fig. 14, the tray TR is supported elastically, and the approach operation to the edge of the tray TR, the operation for holding the edge of the tray TR by means of a hand H, the oscillating operation (for example, the reciprocating motion between G1 and G2) with the tray TR being held, the retreat operation, etc. are taught to the robot RB in advance.

[0075] Also, as shown in Fig. 15, the robot RB may be equipped with a loosening member F such as a leveling plate or a brush-like leveling member to loosen the piled-up article group by using the loosening member F. In this case, an operation suitable for loosening the piled-up article group (for example, the reciprocating motion between G3 and G4) is taught to the robot RB.

[0076] Further, as shown in Figs. 3 and 7, an air gun AG may be provided near the tray TR to loosen the piled-up article group W by an air jet or jet of (or jet of any other gas) blown from the air gun AG. The broken line 100 in the figures indicates a cable 100 connecting the air gun AG to the robot controller 20 or 30 when the air gun AG is used. The air gun AG is operated on command from the robot controller 20 or 30. It may be used together with the shaking device 1 (switching operation, simultaneous operation, etc.) or may be used as a means for loosening substituting for the shaking device 1.

Claims

1. An article picking-up apparatus, comprising:

   a robot;
   articles placing means;
   loosening means having a function of giving a physical action to a group of articles placed on said articles placing means in a piled-up state to loosen the piled-up state; and
   a visual sensor which searches for a group of articles placed on said articles placing means to find at least one holdable article that can be held by said robot in accordance with a predetermined criterion, and obtains data concerning the position of said holdable article,
   said robot being operated so as to hold and pick up said holdable article by using the data concerning the position of said holdable article.

2. The article picking-up apparatus according to claim 1, wherein said visual sensor is a two-dimensional visual sensor.

3. The article picking-up apparatus according to claim 1, wherein said visual sensor is a three-dimensional visual sensor.

4. The article picking-up apparatus according to claim 1, 2 or 3, wherein said criterion is such that an isolated article is taken as a holdable article.

5. The article picking-up apparatus according to claim 1, 2 or 3, wherein said criterion is such that two or a group of several isolated articles contacting with each other is taken as including a holdable article.

6. The article picking-up apparatus according to any claim preceding claim, wherein said physical action is an oscillating motion.

7. The article picking-up apparatus according to claim 6, wherein said physical action is an oscillating motion, and said loosening means includes a shaking device for oscillating said mounting means.

BNSDOCID: <EP__0951968A2_I_>

8. The article picking-up apparatus according to claim 6, wherein said physical action is an oscillating motion, and said loosening means is supported by a robot to which an operation for oscillating said mounting means is taught.

9. The article picking-up apparatus according any one of claims 1 to 5, wherein said loosening means is a levelling member supported by the robot, and an operation for loosening said piled-up state by contacting with said piled-up article group is taught to the robot.

10. The article picking-up apparatus according to any of the claims 1 to 5, wherein said loosening means includes a gas injecting device for loosening said piled-up state by the action of a gas jet.

BNSDOCID: <EP___0951968A2_I_>

Fig.1

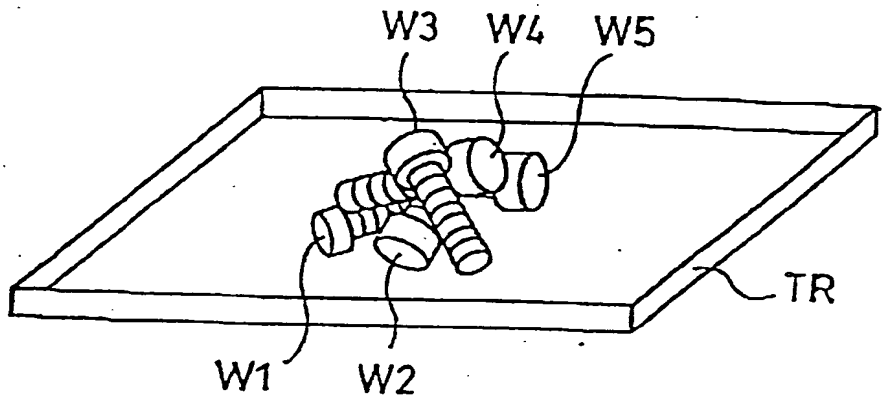
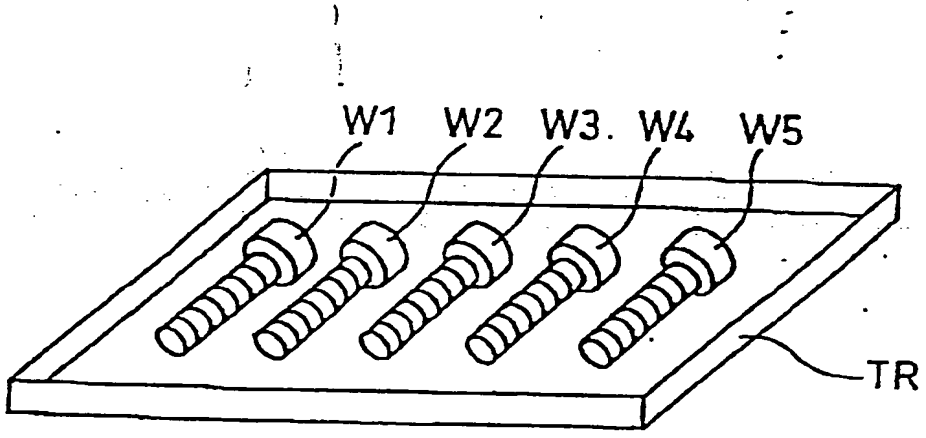


Fig.2



BNSDOCID: <EP___0951968A2_I_>

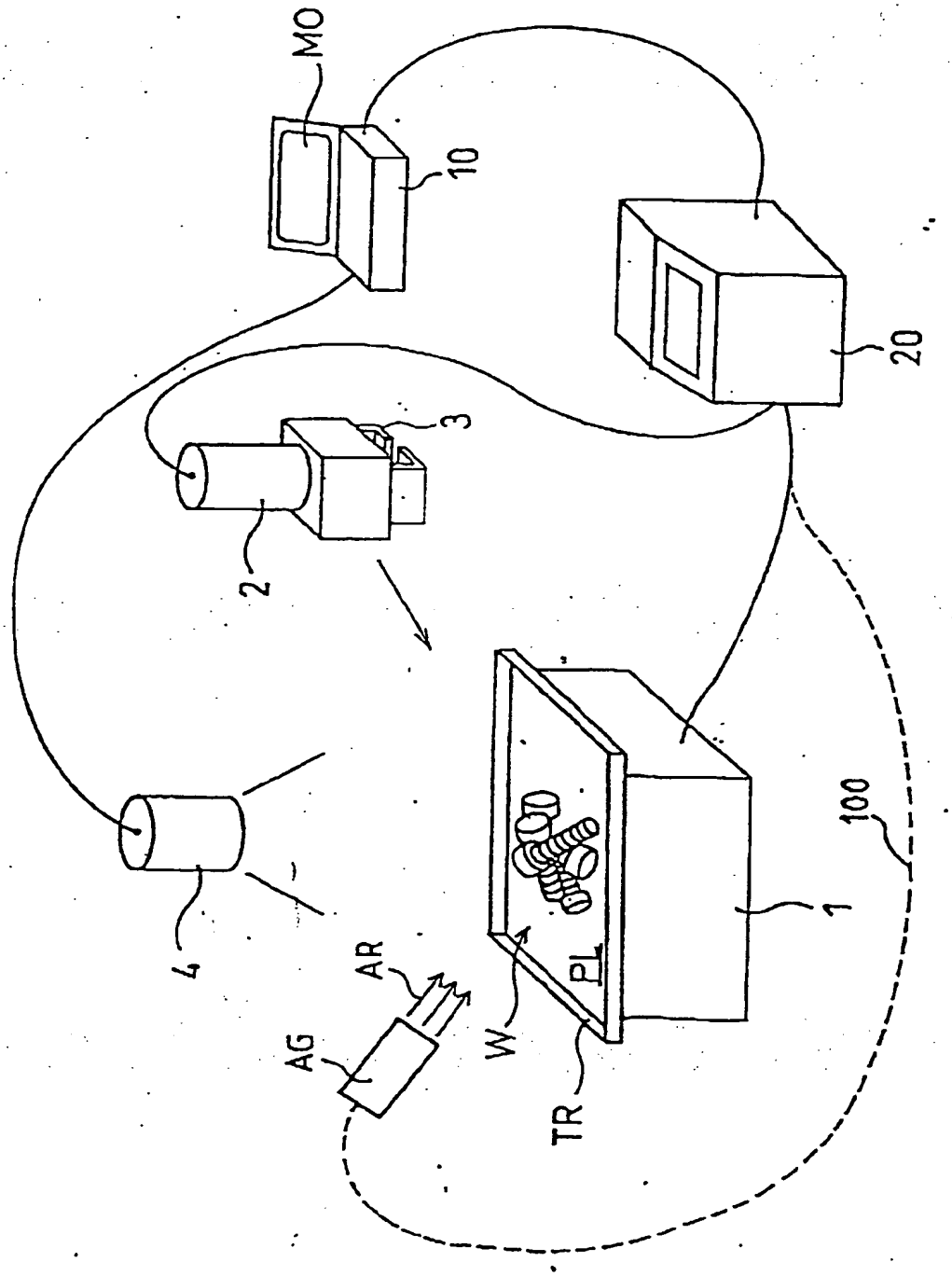
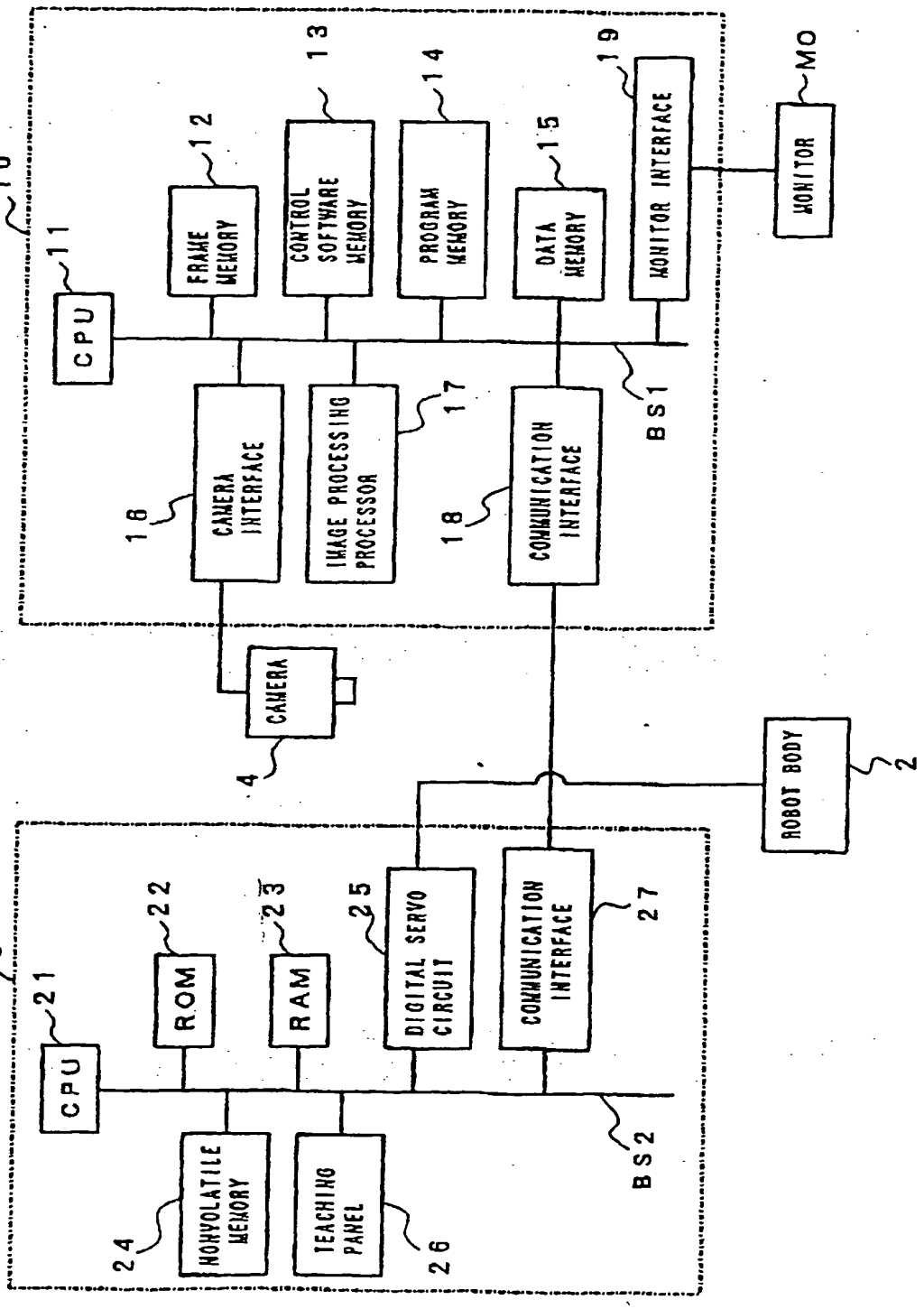


Fig.3

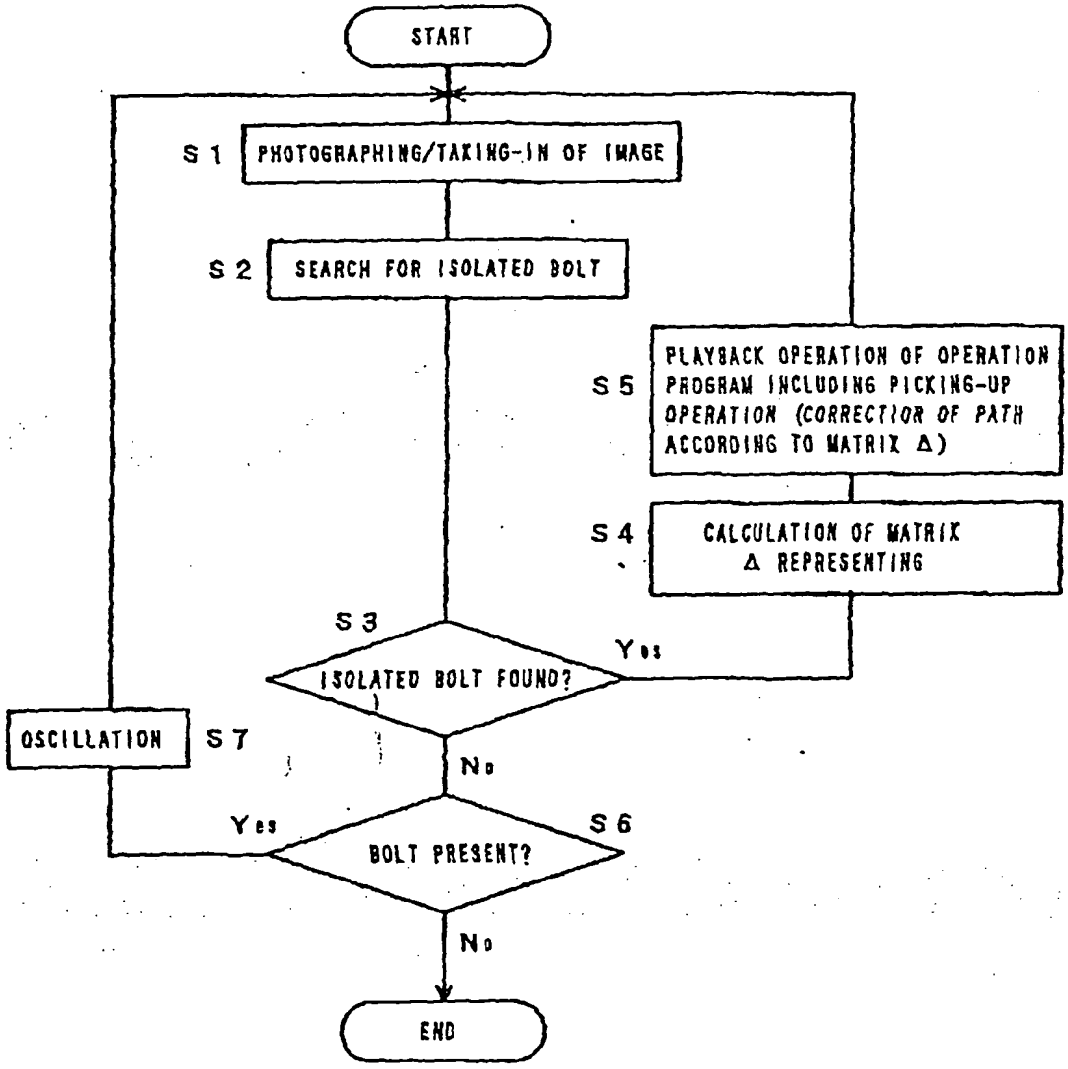
BNSDOCID: <EP___0951968A2_I_>

FIG. 4



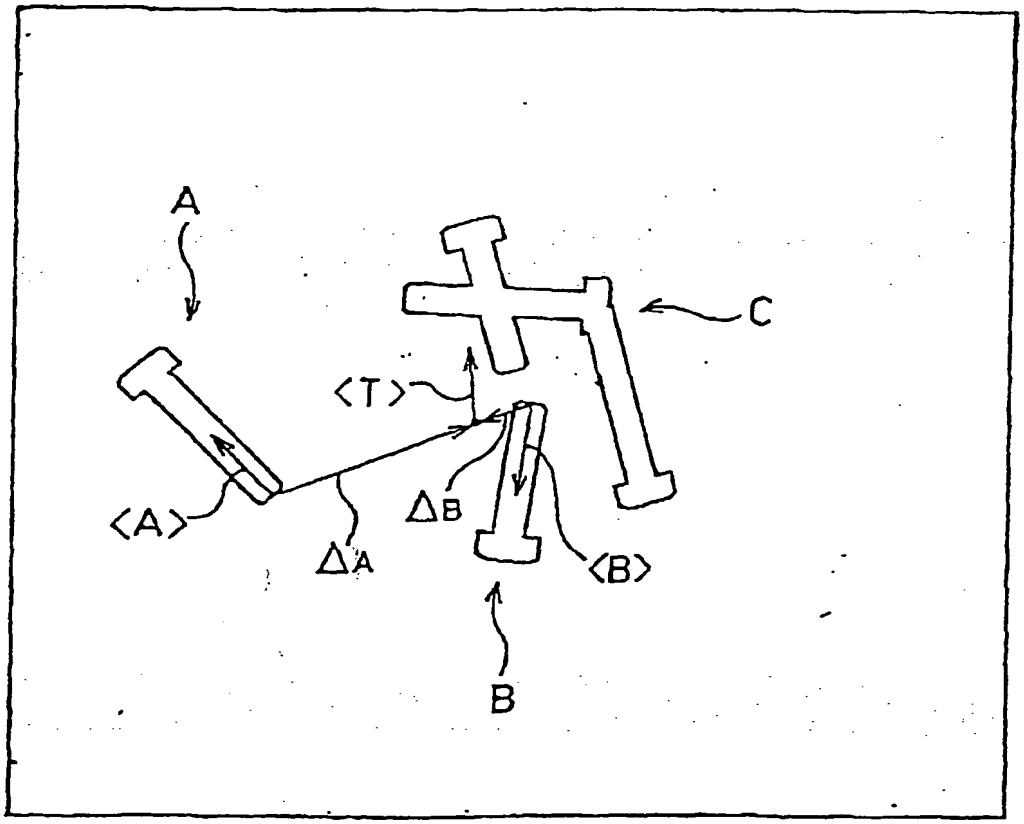
BNSDOCID: <EP___0951968A2_I_>

FIG. 5



BNSDOCID: <EP___0951968A2_I_>

FIG. 6



BNSDOCID: <EP___0951968A2_I_>

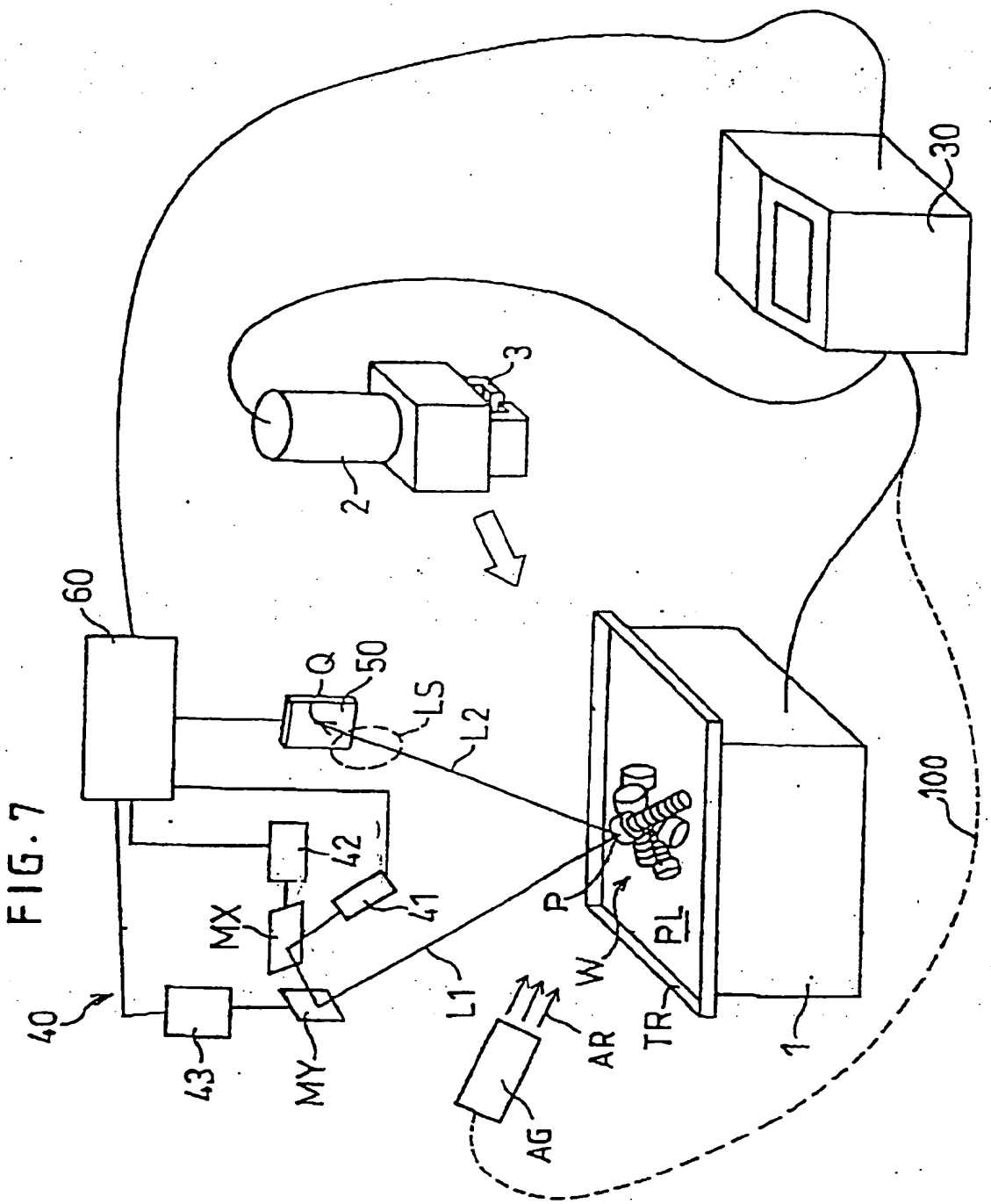
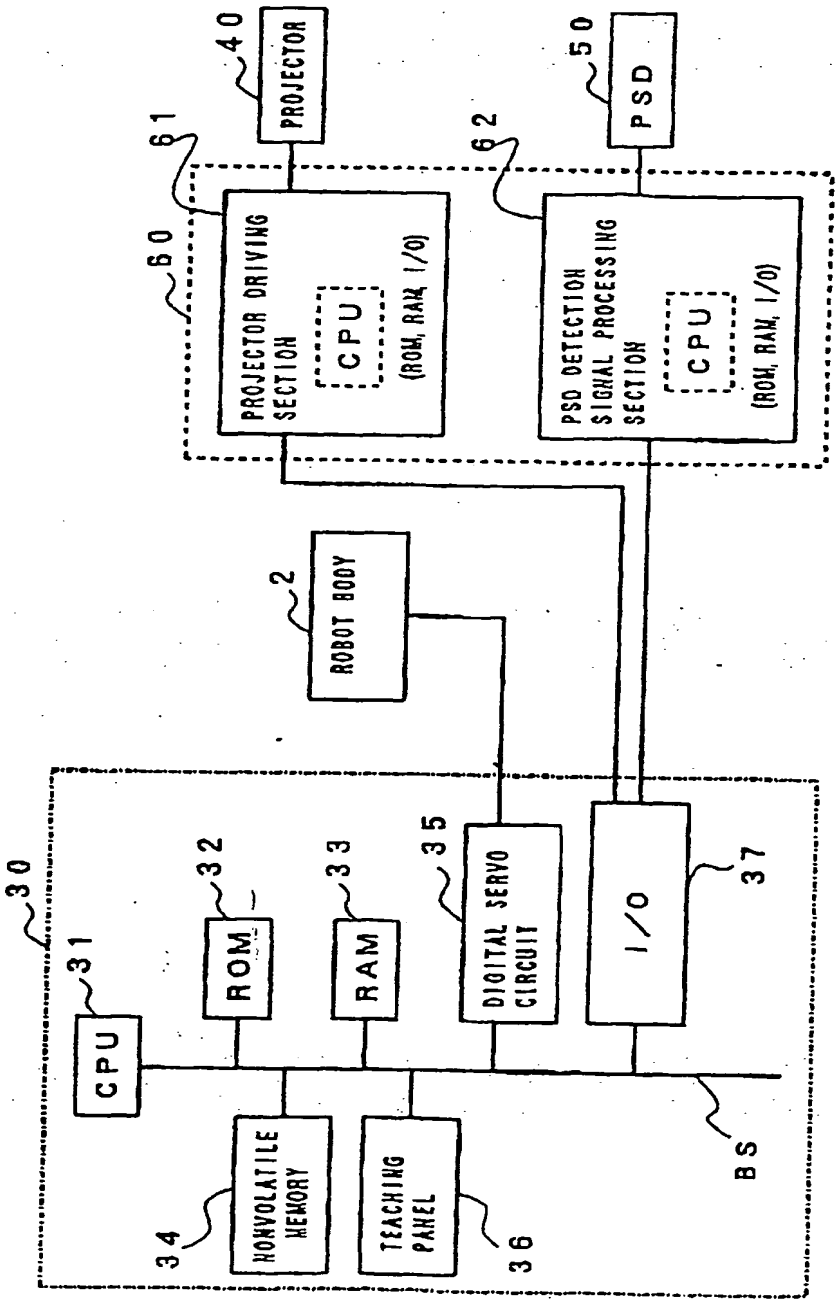


FIG. 7

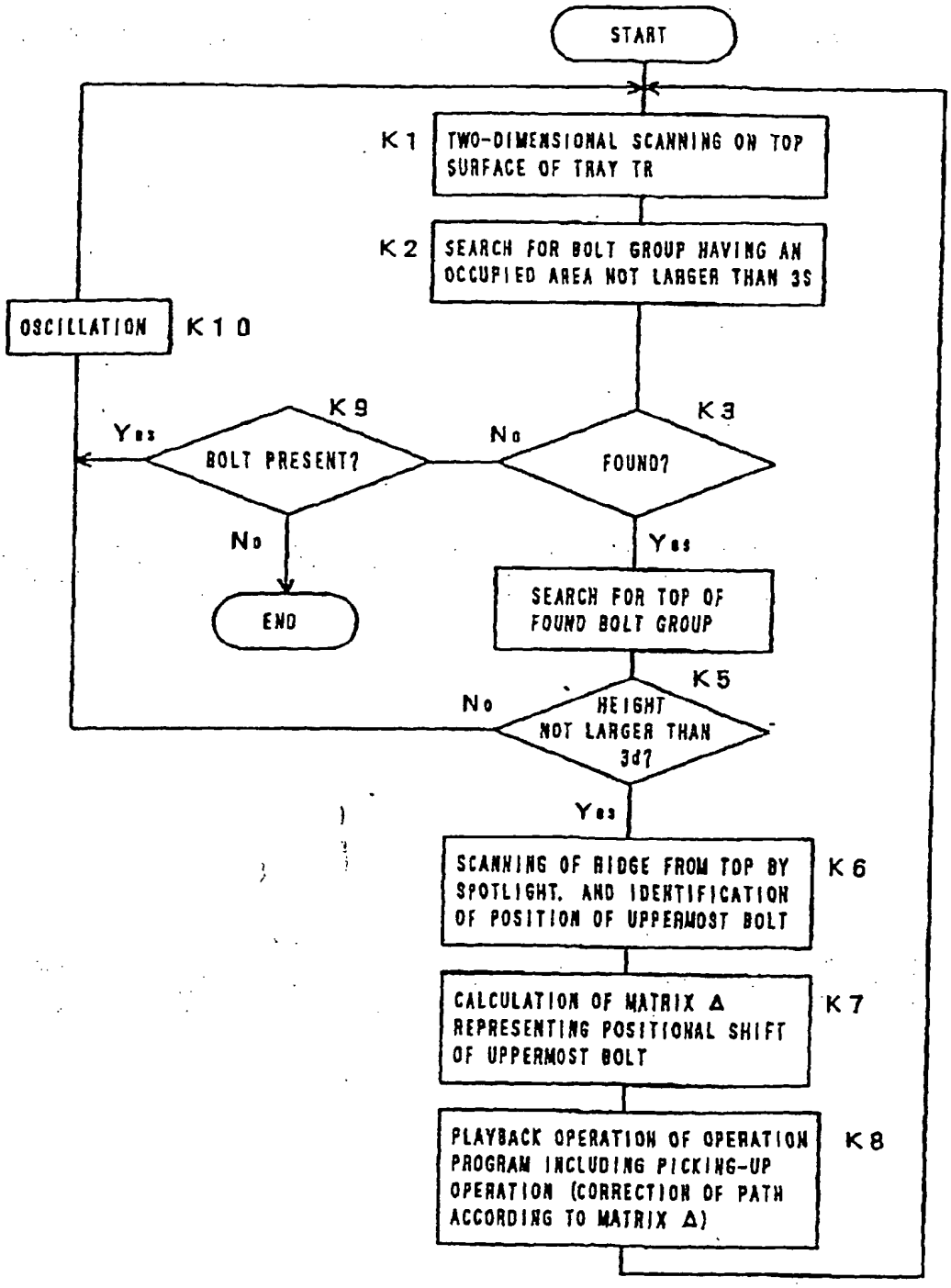
BNSDOCID: <EP___0951968A2_I_>

FIG. 8



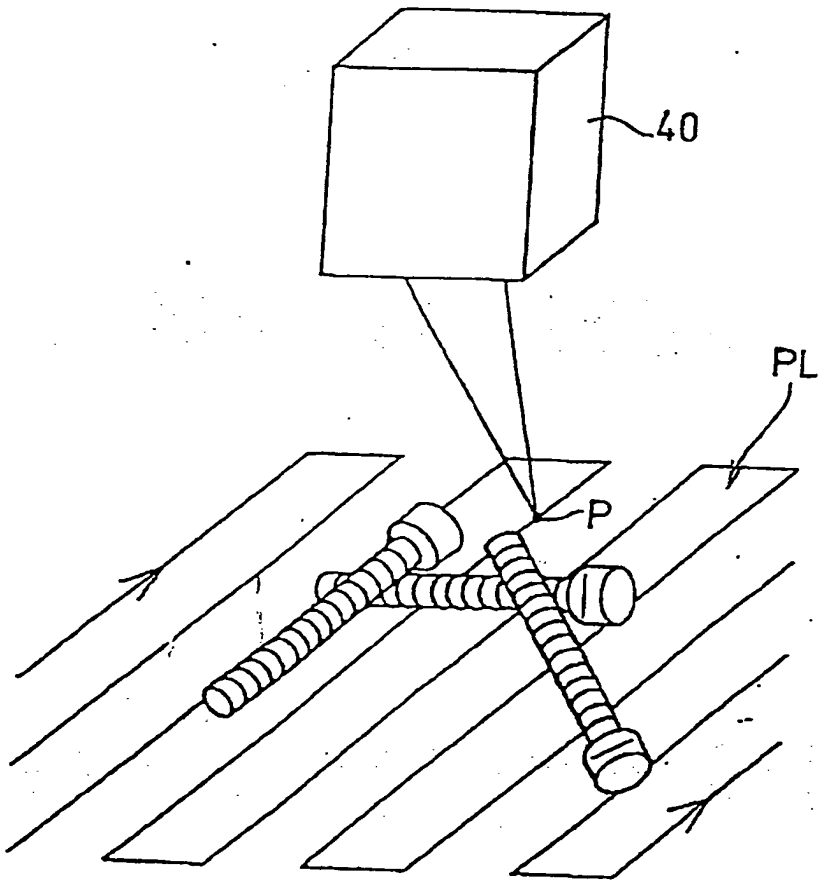
BNSDOCID: <EP___0951968A2_I_>

FIG. 9



BNSDOCID: <EP___0951968A2_I_>

Fig. 10



EPODOCID: <EP___0951968A2_I_>

Fig.11

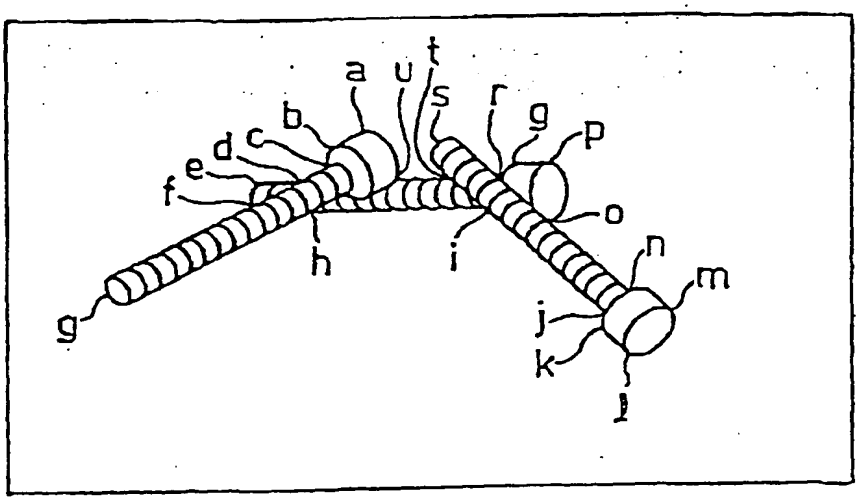
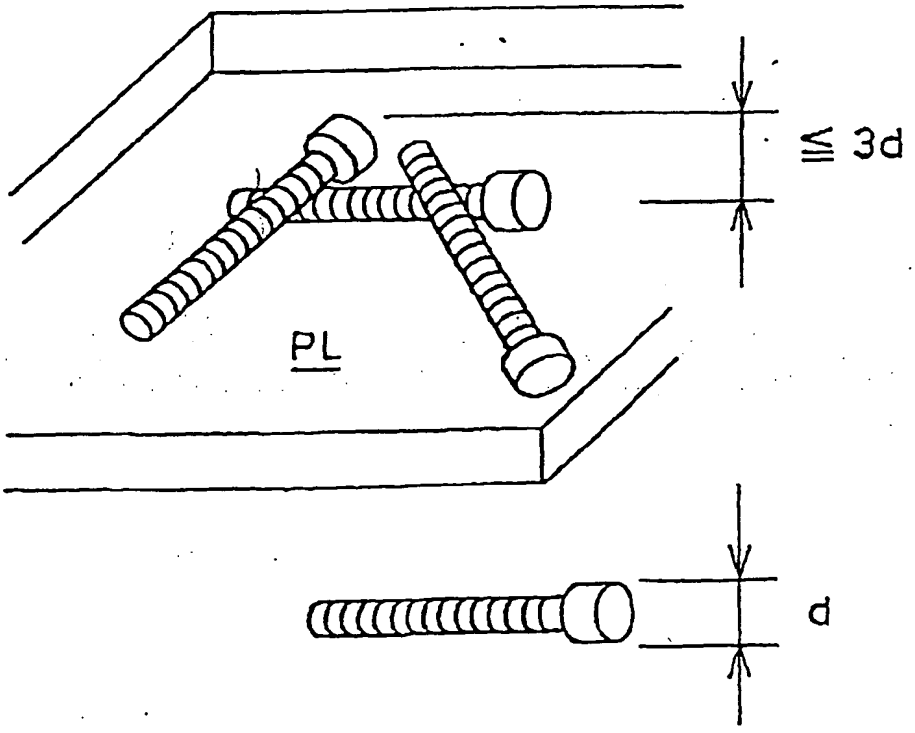
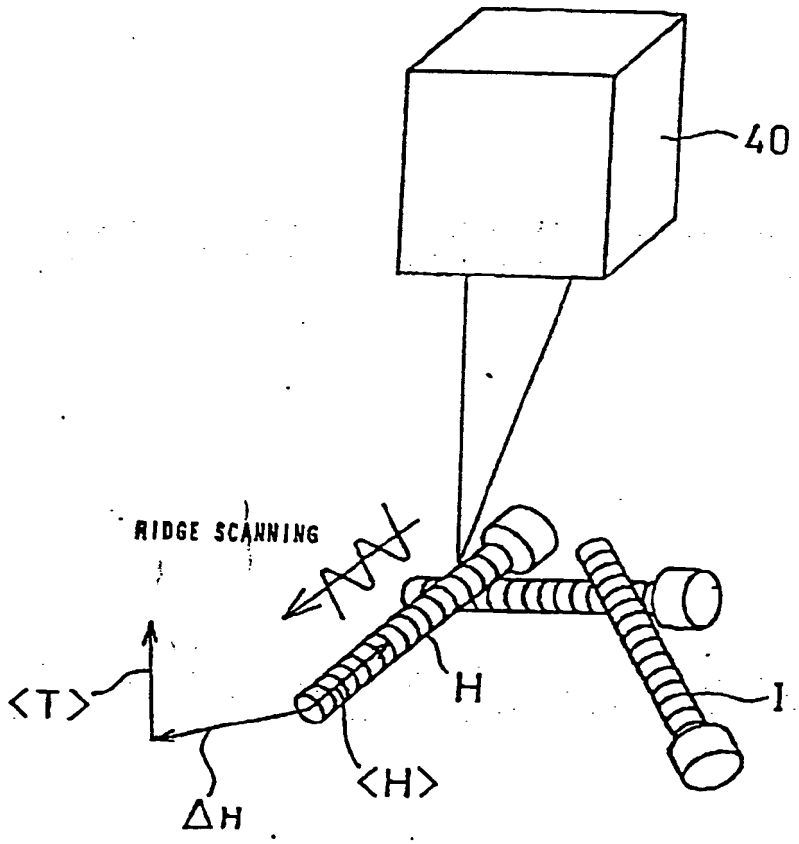


Fig.12



BNSDOCID: <EP___0951968A2_I_>

Fig. 13



BNSDOCID: <EP___0951968A2_I_>

Fig.14

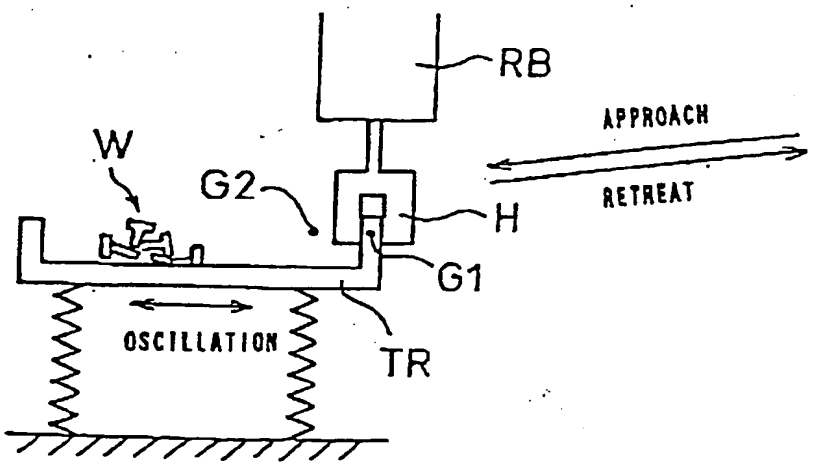
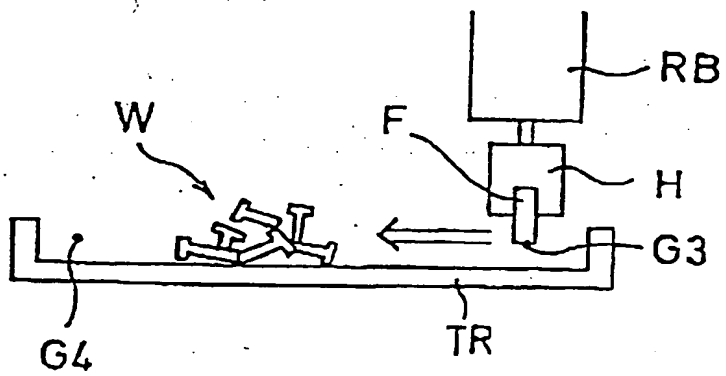


Fig.15



BNSDOCID: <EP___0951968A2_I_>

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 951 968 A3

(12) # EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
02.07.2003 Bulletin 2003/27

(43) Date of publication A2:
27.10.1999 Bulletin 1999/43

(21) Application number: **99303077.4**

(22) Date of filing: **21.04.1999**

(51) Int Cl.[7]: **B25J 9/16**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **21.04.1998 JP 12536898**

(71) Applicant: **FANUC LTD**
Minamitsuru-gun, Yamanashi 401-0597 (JP)

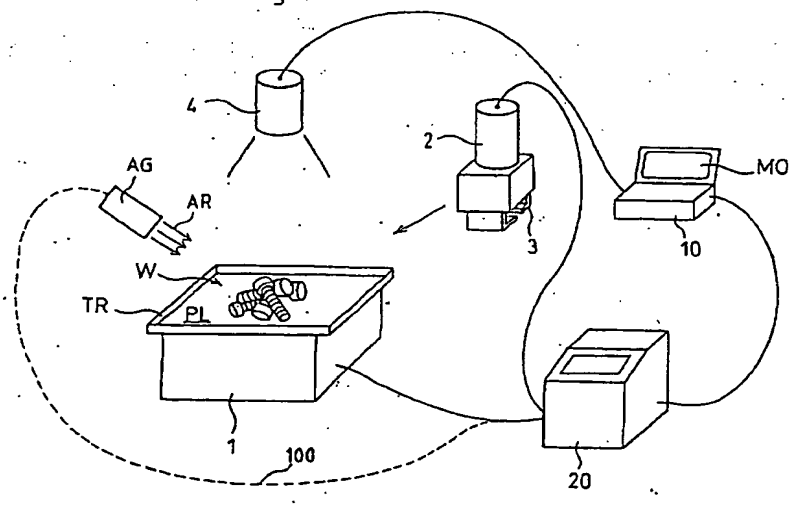
(72) Inventors:
- **Watanabe, Atsushi**
  Minamitsuru-gun, Yamanashi 401-0511 (JP)
- **Hara, Ryuichi**
  Fujiyoshida-shi, Yamanashi 403-0005 (JP)
- **Ban, Kazunori, Fanuc Manshonharimomi**
  Minamitsuru-gun, Yamanashi 401-0511 (JP)
- **Kumiya, Hidetoshi, Fanuc Dai3virakaramatsu**
  Minamitsuru-gun, Yamanashi 401-0511 (JP)

(74) Representative: **Billington, Lawrence Emlyn**
Haseltine Lake & Co.,
Imperial House,
15-19 Kingsway
London WC2B 6UD (GB)

(54) **Article picking-up apparatus**

(57) A group of bolts are supplied onto a placing surface of a tray, an isolated bolt is searched for by a visual sensor, and its deviation from a standard position at the time of teaching is determined. The isolated bolt is picked up by a robot to which a picking-up operation is taught which making a correction of the shift. If no isolated bolt is found, a shaking device 1 is operated to loosen the piled-up bolts, and an isolated bolt newly produced is again searched for by the visual sensor. The isolated bolt, if found, is picked up. The picking-up operation may be performed by searching for an isolated small set of bolts by using a three-dimensional visual sensor. Also, the piled-up bolts may be loosened or disentangled by using a robot equipped with a tool for levelling the pile of bolts or by using a gas jet.

Fig.3



EP 0 951 968 A3

BNSDOCID: <EP___0951968A3_I_>

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 30 3077

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	WO 92 03364 A (INTELLIGENT AUTOMATION SYSTEMS) 5 March 1992 (1992-03-05) * the whole document *	1-4,6,7 5,10	B25J9/16
Y	US 5 041 907 A (SCHMEHL MICHAEL R ET AL) 20 August 1991 (1991-08-20) * column 4, line 12 - line 15 *	5	
Y	PATENT ABSTRACTS OF JAPAN vol. 014, no. 339 (M-1001), 23 July 1990 (1990-07-23) & JP 02 117513 A (SHINKO ELECTRIC CO LTD), 2 May 1990 (1990-05-02) * abstract *	10	
X Y	EP 0 667 124 A (ETHICON INC) 16 August 1995 (1995-08-16) * the whole document *	1-4,6,7 10	
Y	PATENT ABSTRACTS OF JAPAN vol. 013, no. 327 (M-854), 24 July 1989 (1989-07-24) & JP 01 110428 A (HONDA MOTOR CO LTD), 27 April 1989 (1989-04-27) * abstract *	10	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B25J
A	US 3 881 605 A (GROSSMAN DAVID D) 6 May 1975 (1975-05-06) * the whole document *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	9 May 2003	Hauser, L

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

BNSDOCID: <EP___0951968A3_I_>

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 30 3077

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

09-05-2003

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9203364 A	05-03-1992	CA 2090117 A1	26-02-1992
		DE 69122762 D1	21-11-1996
		DE 69122762 T2	15-05-1997
		EP 0544833 A1	09-06-1993
		WO 9203364 A1	05-03-1992
		US 5314055 A	24-05-1994
US 5041907 A	20-08-1991	US 5040056 A	13-08-1991
		AU 7251591 A	21-08-1991
		WO 9111885 A1	08-08-1991
JP 02117513 A	02-05-1990	JP 1935353 C	26-05-1995
		JP 6065568 B	24-08-1994
EP 0667124 A	16-08-1995	US 5568593 A	22-10-1996
		BR 9500090 A	17-10-1995
		CA 2140103 A1	14-07-1995
		CN 1128133 A	07-08-1996
		EP 0667124 A1	16-08-1995
		JP 8056950 A	05-03-1996
		ZA 9500231 A	12-07-1996
JP 01110428 A	27-04-1989	NONE	
US 3881605 A	06-05-1975	DE 2430691 A1	26-06-1975
		FR 2234961 A1	24-01-1975
		GB 1422104 A	21-01-1976

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

BNSDOCID: <EP___0951968A3_I_>

THIS PAGE BLANK (USPTO)